CLAIMS

1. A method of mapping information onto at least two simultaneous carriers (202, 206, 208) having different frequencies in a multi-carrier modulation system, said method comprising the step of:

controlling respective parameters of said at least two carriers such that said information is differential encoded.

2. The method according to claim 1, wherein said controlled parameters of said at least two carriers (202, 206, 208) are respective phases and/or amplitudes of said at least two carriers.

3. The method according to claim 1 or 2, wherein said step of controlling respective parameters of said at least two carriers (202, 206, 208) comprises the step of controlling respective parameters of at least two carriers which are adjacent in the frequency axis direction.

4. The method according to one of claims 1 to 3, further comprising the step of controlling the parameter of one of said at least two carriers (206) in order to define an absolute parameter reference.

5. The method according to one of claims 1 to 4, comprising the step of mapping information onto at least three simultaneous carriers which are equally spaced in the frequency axis direction.

6. A method of performing a multi-carrier modulation of a bitstream (102) in a digital broadcasting transmitter (100), said method comprising the steps of:

phase shift keying (220) said bitstream by associating a

respective phase shift to one or more bits of said bit-stream; and

differential phase encoding said phase shifts by controlling the phase of a first carrier based on a phase of a simultaneous second carrier and said phase shift, said first and second carriers having different frequencies.

7. The method according to claim 6, wherein the step of differential phase encoding comprises the steps of:

determining (222) the phase of a first carrier based on a phase of a simultaneous second carrier and said phase shift, said first and second carriers having different frequencies;

associating (232) a complex carrier symbol to each phase shift;

assembling (234) a multi-carrier modulation symbol (200) based on said complex carrier symbols; and

performing an inverse Fourier transform (236).

8. The method according to claim 6 or 7, wherein said second carrier is arranged adjacent to said first carrier in the frequency axis direction.

9. The method according to one of claims 6 to 8, wherein said step of phase shift keying (220) said bitstream comprises the step of performing a quadrature phase shift keying using a Gray mapping.

10. The method according to one of claims 6 to 9, comprising the step of controlling the phase of one carrier in order to define an absolute phase reference.

11. The method according to one of claims 6 to 10, comprising the step of controlling the phases of at least three simultaneous carriers which are equally spaced in the frequency axis direction.

12. A method of de-mapping information based on at least two simultaneous encoded carriers having different frequencies in a multi-carrier demodulation system, said method comprising the step of:

    recovering said information by differential decoding (142) of respective parameters of said at least two carriers.

13. The method according to claim 12, wherein said step of differential decoding (142) comprises the step of differential decoding respective phases and/or amplitudes of said at least two carriers.

14. The method according to claim 12 or 13, wherein said step of recovering said information comprises the step of decoding respective parameters of at least two carriers which are adjacent in the frequency axis direction.

15. The method according to one of claims 12 to 14, wherein said step of recovering said information comprises the step of decoding respective parameters of at least three simultaneous carriers which are equally spaced in the frequency axis direction.

16. A method of performing a demodulation of a multi-carrier modulated signal in a digital broadcasting system, said method comprising the steps of:

    differential phase decoding phase shifts based on a phase difference between simultaneous carriers having different frequencies;

recovering bits of a bitstream from said phase shifts.

17. The method according to claim 16, wherein said step of differential phase decoding comprises the steps of:

performing a Fourier transform (140) to derive a multi-carrier modulated symbol, said multi-carrier modulated symbol comprising complex carrier symbols; and

recovering (142) respective phase shifts from said complex carrier symbols.

18. The method according to claim 16 or 17, wherein said step of differential phase decoding comprises the step of differential phase decoding based on a phase difference between simultaneous carriers which are adjacent in the frequency axis direction.

Sub A 19. The method according to one of claims 16 to 18, wherein said step of recovering bits of a bitstream from said phase shift comprises the step of demodulating said phase shifts using a Gray de-mapping.

20. The method according to one of claims 16 to 19, wherein said step of differential phase decoding comprises the step of differential phase decoding based on phase differences between at least three simultaneous carriers which are equally spaced in the frequency axis direction.

21. A method of performing an echo phase offset correction in a multi-carrier demodulation system, comprising the steps of:

differential phase decoding (142) phase shifts based on a phase difference between simultaneous carriers having different frequencies;

determining an echo phase offset for each decoded phase shift by eliminating (500) phase shift uncertainties corresponding to codeable phase shifts from said decoded phase shift;

averaging (520) said echo phase offsets in order to generate an averaged offset; and

correcting (524) each decoded phase shift based on said averaged offset.

22. The method according to claim 21, wherein said step of differential phase decoding comprises the step of differential phase decoding phase shifts based on a phase difference between simultaneous carriers which are adjacent in the frequency axis direction.

23. The method according to claim 21 or 22, wherein said step of differential phase decoding comprises the step of differential phase decoding phase shifts based on phase differences between at least three simultaneous carriers which are equally spaced in the frequency axis direction.

24. The method according to one of claims 21 to 23, further comprising a step of comparing (516) an absolute value of a symbol associated with a respective decoded phase shift with a threshold, wherein only phase shifts having associated therewith symbols having an absolute value exceeding said threshold are used in said step of averaging said echo phase offsets.

25. A method of performing an echo phase offset correction in a multi-carrier demodulation system, comprising the steps of:

differential phase decoding phase shifts based on a

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phase difference between simultaneous carriers having different frequencies, said phase shifts defining signal points in a complex plane;

pre-rotating said signal points into the sector of said complex plane between -45° and +45°;

determining parameters (a, b) of a straight line approximating the location of said pre-rotated signal points in said complex plane;

determining a phase offset based on said parameters (a, b); and

correcting each decoded phase shift based on said phase offset.

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26. The method according to claim 25, wherein said simultaneous carriers are equally spaced in the frequency axis direction.

27. The method according to claim 25 or 26, wherein said step of determining said parameters (a, b) comprises a least squares method for selecting those parameters which minimize the deviations of said pre-rotated signal points from said straight line.

28. The method according to claim 27, wherein said parameters (a, b) are determined as follows:

$$b = \frac{\sum_{i=1}^{K}(x_i - \overline{x}) \cdot y_i}{\sum_{i=1}^{K}(x_i - \overline{x})^2}, \quad a = \overline{y} - \overline{x} \cdot b \qquad \text{(Eq.25)}$$

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{K} x_i, \quad \overline{y} = \frac{1}{N}\sum_{i=1}^{K} y_i \qquad \text{(Eq.26)}$$

wherein x and y designate the coordinates of the signal points in the complex plane,

i is an index from 1 to N, and

K is the number of signal points.

29. The method according to claim 28, wherein said phase offset (φ_k) is determined as follows:

$$\varphi_k = \begin{cases} -atan\left(\dfrac{a + b\sqrt{|v_k|^2(1+b^2) - a^2}}{-ab + \sqrt{|v_k|^2(1+b^2) - a^2}}\right) & \text{for } |v_k|^2 \geq \dfrac{a^2}{1+b^2} \\ atan\left(\dfrac{1}{b}\right) & \text{for } |v_k|^2 < \dfrac{a^2}{1+b^2} \end{cases} \quad \text{(Eq.23)}$$

wherein v_k is a given decision variable.

30. A mapping device for mapping information onto at least two simultaneous carriers (202, 206, 208) having different frequencies, for a multi-carrier modulation system, said device comprising means for controlling respective parameters of said at least two carriers such that said information is differential encoded.

31. The device according to claim 30, wherein said means for controlling respective parameters of said at least two carriers (202, 206, 208) is adapted to control respective phases and/or amplitudes of said at least two carriers.

32. The device according to claim 30 or 31, wherein said means for controlling respective parameters of said at least two carriers (202, 206, 208) comprises means for controlling respective parameters of at least two carriers which are adjacent in the frequency axis direction.

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33. The device according to one of claims 30 to 32, further comprising means for controlling the parameter of one (206) of said at least two carriers such that an absolute parameter reference is defined by said carrier.

34. The device according to one of claims 30 to 33, further comprising means for controlling the parameters of at least three carriers which are equally spaced in the frequency axis direction.

35. A multi-carrier modulator for performing a multi-carrier modulation of a bitstream (102), for a digital broadcasting transmitter (100), said modulator comprising:

means for phase shift keying (220) said bitstream by associating a respective phase shift to one or more bits of said bitstream; and

a differential phase encoder for differential phase encoding said phase shifts by controlling the phase of a first carrier based on a phase of a simultaneous second carrier and said phase shift, said first and second carriers having different frequencies.

36. The modulator according to claim 35, wherein said differential phase encoder comprises:

means (222) for determining the phase of a first carrier based on a phase of a simultaneous second carrier and said phase shift, said first and second carriers having different frequencies;

means (232) for associating a complex carrier symbol to each phase shift;

means (234) for assembling a multi-carrier modulation symbol based on said complex carrier symbols; and

means (236) for performing an inverse Fourier transform.

37. The modulator according to claim 35 or 36, wherein said means (222) for determining said phase of said first carrier is adapted to determine said phase based on a phase of a simultaneous second carrier which is arranged adjacent to said first carrier in the frequency axis direction and said phase shift.

38. The modulator according to one of claims 35 to 37, wherein said means (220) for phase shift keying said bitstream comprises means for performing a quadrature phase shift keying using a Gray mapping.

39. The modulator according to one of claims 35 to 38, comprising means for controlling the phase of one carrier in order to define an absolute phase reference.

40. The modulator according to one of claims 35 to 39, comprising means for controlling the phases of at least three carriers which are equally spaced in the frequency axis direction.

41. A de-mapping device for de-mapping information based on at least two simultaneous encoded carriers having different frequencies, for a multi-carrier demodulation system (130), said de-mapping device (142) comprising:

means for recovering said information by differential decoding of respective parameters of said at least two carriers.

42. The device according to claim 41, wherein said means for recovering said information is adapted to differential decode respective phases and/or amplitudes of said at least two carriers.

43. The device according to claim 41 or 42, wherein said

means for recovering said information comprises means for decoding respective parameters of at least two carriers which are adjacent in the frequency axis direction.

44. The device according to one of claims 41 to 43, wherein said means for recovering said information comprises means for decoding respective parameters of at least three simultaneous carriers which are equally spaced in the frequency axis direction.

45. A demodulator for demodulating a multi-carrier modulated signal, for a digital broadcasting system, said demodulator comprising:

a differential phase decoder for decoding phase shifts based on a phase difference between simultaneous carriers having different frequencies;

means for recovering bits of a bitstream from said phase shifts.

46. The demodulator according to claim 45, wherein said differential phase decoder comprises:

means (140) for performing a Fourier transform to derive a multi-carrier modulated symbol, said multi-carrier modulated symbol comprising complex carrier symbols; and

means (142) for recovering respective phase shifts from said complex carrier symbols.

47. The demodulator according to claim 45 or 46, wherein said differential phase decoder is adapted for decoding phase shifts based on a phase difference between simultaneous carriers which are adjacent in the frequency axis direction.

48. The demodulator according to one of claims 45 to 47, wherein said means for recovering bits of a bitstream from said phase shift comprises a Gray de-mapper.

49. The demodulator according to one of claims 45 to 48, wherein said simultaneous carriers are equally space in the frequency axis direction.

50. An echo phase offset correction device for a multi-carrier demodulation system, comprising:

a differential phase decoder (142) for decoding phase shifts based on a phase difference between simultaneous carriers having different frequencies;

means for determining an echo phase offset for each decoded phase shift comprising means (500) for eliminating phase shift uncertainties corresponding to codeable phase shifts from said decoded phase shift;

means (520) for averaging said echo phase offsets in order to generate an averaged offset; and

means (524) for correcting each decoded phase shift based on said averaged offset.

51. The device according to claim 50, wherein said differential phase decoder is adapted for decoding said phase shifts based on a phase difference between simultaneous carriers which are adjacent in the frequency axis direction.

52. The device according to claim 50 or 51, further comprising means (516) for comparing an absolute value of a symbol associated with a respective decoded phase shift with a threshold, wherein said means for averaging said phase offsets only uses phase shifts having associated therewith symbols having an absolute value

exceeding said threshold.

53. The device according to one of claims 50 to 52, wherein said differential phase decoder is adapted for decoding said phase shifts based on phase differences between at least three simultaneous carriers which are equally spaced in the frequency axis direction.

54. An echo phase offset correction device for a multi-carrier demodulation system, comprising:

a differential phase decoder for decoding phase shifts based on a phase difference between simultaneous carriers having different frequencies, said phase shifts defining signal points in a complex plane;

means for pre-rotating said signal points into the sector of said complex plane between -45° and +45°;

means for determining parameters (a, b) of a straight line approximating the location of said pre-rotated signal points in said complex plane;

means for determining a phase offset based on said parameters (a, b); and

means for correcting each decoded phase shift based on said phase offset.

55. The device according to claim 54, wherein said differential phase decoder comprises means for decoding phase shifts of at least three simultaneous carriers which are equally spaced in the frequency axis direction.

56. The device according to claim 54 or 55, wherein said means for determining said parameters (a, b) comprises means for performing a least squares method for

selecting those parameters which minimize the deviations of said pre-rotated signal points from said straight line.

57. The device according to claim 56, wherein said means for determining said parameters (a, b) calculates said parameters (a, b) as follows:

$$b = \frac{\sum_{i=1}^{K}(x_i - \overline{x}) \cdot y_i}{\sum_{i=1}^{K}(x_i - \overline{x})^2}, \quad a = \overline{y} - \overline{x} \cdot b \qquad \text{(Eq.25)}$$

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{K} x_i, \quad \overline{y} = \frac{1}{N}\sum_{i=1}^{K} y_i \qquad \text{(Eq.26)}$$

wherein x and y designate the coordinates of the signal points in the complex plane,

i is an index from 1 to N, and

K is the number of signal points.

58. The device according to claim 57, wherein said means for determining said phase offset (φ_k) calculates said phase offset (φ_k) as follows:

$$\varphi_k = \begin{cases} -atan\left(\dfrac{a + b\sqrt{|v_k|^2(1+b^2) - a^2}}{-ab + \sqrt{|v_k|^2(1+b^2) - a^2}}\right) & \text{for } |v_k|^2 \geq \dfrac{a^2}{1+b^2} \\ atan\left(\dfrac{1}{b}\right) & \text{for } |v_k|^2 < \dfrac{a^2}{1+b^2} \end{cases} \qquad \text{(Eq.23)}$$

wherein v_k is a given decision variable.